GROUNDWATER UNDER THE DIRECT INFLUENCE OF SURFACE WATER

FINAL REPORT

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ABSTRACT

As part of the June 29, 1989 Amendments to the Safe Drinking Water Act each state was required to determine which community and non-community public water supply systems use groundwater which is under the direct influence of surface water. Because of the large number of systems to be evaluated in Wisconsin (approximately 15,000) it was necessary to develop a methodology for evaluating all the public water supplies without conducting a site specific investigation of every supply.

A study was conducted to aid in developing the proposed methodology. Eighteen wells were selected for a one time evaluation based on recurring total coliform positives and proximity to a surface water. Of the original eighteen wells three were selected for longer term sampling and more intensive hydrogeologic evaluation. While the hydrogeologic evaluation indicated that the three wells would be influenced by surface water, the sampling results showed that the wells were not under the direct influence of surface water. The study concluded that:

- Giardia cysts are not routinely present in the most susceptible municipal groundwater supplies.

- Multiple sampling events cannot adequately determine the potential for giardia contamination of groundwater supplies.

Based on this study, the State of Wisconsin has developed a methodology for classifying a groundwater as under the direct influence of surface water. The methodology evaluates:

- Raw water total coliform test results

- Well construction, and

- Well location

Using this methodology the State has determined that there are no municipal groundwater systems under the direct influence of surface water. Because the wells serving other-than-municipal (OTM) and non-community water systems were also constructed under long standing well construction codes and are constructed in the same aquifer systems as the municipal wells, the same rnethodology will be employed by the state to evaluate the OTM and non-Community wells.

TABLE OF CONTENTS

**GROUNDWATER UNDER THE DIRECT
INFLUENCE OF SURFACE WATER**

INTRODUCTION

This study is intended to establish a methodology for determining if specific groundwater systems should be classified as under the direct influence of surface water. This report is a compilation and analysis of results collected between May 1990 and May 1992 as part of a study of groundwater throughout the State of Wisconsin. Those wells most likely to be influenced by surface waters were chosen for investigation. The study was conducted in response to the requirements established in the Federal Register, Volume 54, No. 124, June 29, 1989, Amendments to the Safe Drinking Water Act. These amendments require that "by June 29, 1994 and June 29, 1999 each state must determine which community and non-community public water systems, respectively, use groundwater which is under the direct influence of surface water".

BACKGROUND

The study design and goals were based on a number of issues illustrated by the following quotes from the Federal Register, Volume 54, No. 124:

- "The State determination of direct influence may be based on site-specific measurements of water quality and/or documentation of well construction characteristics and geology with field evaluation." page 27489

- "There is no analytical method for measuring Giardia lamblia cysts for which the precision, efficiency, and sensitivity have been adequately defined; no reliable validation procedures or laboratory certification procedures are available, and very large numbers of samples would be needed to accurately quantify levels of cyst occurrence. page 27494

- 'Giardia lamblia cysts pose significant risks to health for systems using surface waters, but usually not for systems using groundwater because these protozoan cysts are removed from water by natural filtration processes... page 27498

- 'Turbidity is not a useful indicator of treatment effectiveness for most groundwater systems since most particulates are already being removed by natural filtration processes..." page 27488

- "Simply put, if a groundwater system is subject to Giardia contamination (unless the contamination originates within the distribution system), states should classify it as a source under the direct influence of surface water and thus subject to the treatment requirements of this rule. It is important to note that the intent of this rule is not to regulate viral and bacterial contamination in systems using groundwater..." page 27489

Because of the large number of systems in Wisconsin to be evaluated, approximately 1,300 community systems and 14,000 noncommunity systems, a study was proposed to evaluate a screening mechanism for determining groundwater under the direct influence of surface water. In the Wisconsin Department of Natural Resources comments to the U. S - EPA on the proposed surface water treatment rule, it was estimated that , because 99% of Wisconsin's wells are constructed in "unconfined" aquifers, it would take 87 full time employees one year to evaluate all community wells in Wisconsin**.**

Coliform bacteria was chosen as a potential screening mechanism because of its ubiquitous nature, its smaller size when compared to Giardia and because of its short time to inactivity when compared to Giardia (Coliform 17 days @ 9.5-12.5^{o} C till 99% ineffectivity), Berger, P.S., and Argaman, Y., "Assessment of Microbiology and Turbidity Standards of Water", USEPA 570/9-83-001 (July 1983) vs. (Giardia 2 months @ 8^{o}C) Bingham, A.K., et al 1979, Giardia. Exp. Parasitol. 47:284.

STUDY GOALS

The overall study goals are to evaluate three issues in order to develop a methodology for classifying groundwater as under the direct influence of surface water. These issues are:

- The extent of groundwater systems in Wisconsin that may be classified as groundwater under the direct influence of surface water as defined in Federal Register, Vol. 54, No. 124 and NR 109.04(20) WAC.
- The use of chronic bacteriologically "unsafe' (total coliform positive) water problems as a screening mechanism for groundwater systems to be classified under the direct influence of surface water.
- The use of other indicator parameters as potential surrogates to be used when determining groundwater as under the direct influence of surface water.

STUDY DESIGN

The study is to be accomplished in three phases. Phase I will consist of a one-time investigation at a number of sites throughout the state. Phase II will consist of a longer duration investigation at a select number of the worst case sites identified in Phase I. Phase III will consist of collecting and assessing hydrogeologic data for the sites investigated in Phases I and II.

Phase I: One time sampling, 8 hours in duration under continuous pumping conditions.

Parameter	Sampling, Frequency
Macroorganisms (Giardia, insects, algae, crustaceans, etc.)	Continuous collection for 8 hours
Total Coliform Bacteria	Hourly

Temperature	Every 15 minutes
Turbidity	Every 15 minutes
Conductivity	Every 15 minutes
Hardness	Hourly

Temperature, turbidity, conductivity. and hardness were selected because influence of surface water could be shown by significant variations of these parameters during a pumping cycle making these parameters potential surrogates for giardia when determining groundwater under the direct influence of surface water.

Phase II: 6 sampling events, 8 hours in duration for each event under continuous pumping conditions.

Parameter	Sampling Frequency
Macroorganisms	Continuous collection for 8 hours
Total Coliform Bacteria	Two samples (one at the start and one at the end of the 8 hour filtration run)

Phase III:

Collect: Well depth, casing depth, aquifer type, transmissivity, specific capacity, storativity, physical proximity to surface waters, and total pumpage (during the sampling and during normal operation).

Calculate:Zone of influence and time of travel.

PHASE I

SITE SELECTION

The Phase I investigation consisted of 20 separate samplings. The sampling sites were selected primarily on 1989 bacteriological raw water sampling results. Eighteen sites were selected. The sites represent locations with periodic raw water total coliform positives with the exception of Neillsville well #4 and Madison well #19. Repeat sampling was conducted at two locations, well #3 at Neillsville, and well #3 at Marathon. Of the 18 sites, 10 locations were proximate to surface water. One site, Madison well #19, was selected as a control.

'Unsafe' Sites	'Unsafe' and Proximate to Surfare Water	Control
Dickeyville #2	Cadott #3	Madison #19

Durand #4	Greenwood #1
Kellnersville #1	Kewaunee #2
Pepin #2	Loyal #1
Sherwood #1	Maiden Rock #1
Sturgeon Bay #10	Marathon #3
Thorp #8	Marshfield #16
	Neillsville #3
	Neillsville #4 (only proximate to surface water)
	Rhinelander #4

SAMPLE COLLECTION

Macroorganisms: A portable 1 micron filter was attached to a hose bib within the pumphouse at each well. The flow was throttled to provide a flow rate of approximately 2 gpm through the filter and water was filtered for 8 hours. Approximately 1,000 gallons was filtered. Upon completion the filter was iced and packaged for delivery to the State Laboratory of Hygiene.

Bacteriological: Eight samples were collected for bacteriological analyses (1 per hour).

Hardness: Eight samples were collected for hardness analyses (1 per hour).

Turbidity, conductivity, and temperature: Water was drawn from a sample tap every 15 minutes and analyzed for turbidity, conductivity, and temperature using a Hach portable turbidimeter, and a Hach portable conductivity/temperature meter. This did not occur at Neillsville and Cadott because the equipment was not available in the early stage of the study.

PHASE I SAMPLE RESULTS

The turbidity, conductivity, and temperature results shown in Table 1 are ranges of results of samples collected at 15 minute intervals for the 8 hour sample period. The bacteriological results shown in Table I are the highest count identified in the 8 samples collected during the 8 hour sample period.

As can be seen in Table 1 all of the wells experienced changes in turbidity, conductivity, and temperature. The most significant change was experienced in the turbidity level at Greenwood well #1 (from 0.23 to 82 NTUs). However, rather than an indicator of surface water influence, the reading resulted from overpumping of the dug well and disturbing the collected bottom sediments. Maiden Rock well #1 (a Sandstone well) experienced a significant increase in turbidity (0. 18 to 40 NTUs). The turbidity increase was a result of a pump surge caused by a significant pressure drop within the distribution system. The water utility was flushing fire hydrants at the time and the pressure dropped from 60 psi to 38 psi. A large temperature difference was also noted at Loyal well #1 (9.5'C to 11.6'C). The increase in temperature was not accompanied by a corresponding increase in turbidity or conductivity and no organisms that would confirm the direct influence of surface water were present. Free living bacteria (unspeciated, nonpathogenic bacteria), iron bacteria, and iron oxides were reported at a number of the sampling locations. However, at three locations significant macroorganisms were identified; Greenwood (fungal spores, plant cells and diatoms); Loyal (fungus); and Marathon (Giardia). The organisms detected at Loyal and Greenwood are most likely inhabiting the wells as the wells are large diameter (24'-Greenwood #1, 14'-Loyal #1) and would provide habitat for the organisms. Giardia was detected in the original sampling at Marathon #3. 'Me well was resampled during Phase I and no Giardia were observed. The detection of giardia at Marathon #3 made this location a candidate for additional sampling proposed for Phase II of this study.

DISCUSSION AND CONCLUSIONS

The data collected do not indicate a continuing direct influence of surface water at any of the sampling locations. The Giardia positive at Marathon was not confirmed in the second sampling. The positive giardia result is puzzling, especially, because the coliform sampling was *safe" (total coliform negative) during both sampling events. As previously discussed the data collected do indicate variations in temperature, conductivity, and turbidity at a number of the sampling sites and, macroorganisms were present in 3 of the 20 filtered samples. However, the data were insufficient to substantiate direct influence of surface water at any of the 18 sampling sites.

Based on the sampling conducted it is concluded:

- Data from turbidity, conductivity, and temperature collected during an 8 hour sampling period is not sufficient to determine the potential for surface water influence.

It can also be conjectured that routine monitoring of these parameters would not adequately reflect the potential for Giardia contamination of groundwater since conductivity and temperature are not affected by filtration and the turbidities encountered are extremely low.

- Giardia contamination is not routinely present in the most susceptible groundwaters serving municipal wells in Wisconsin.

- The coliform bacteria test is not an ideal surrogate for the Giardia test because it appears from the results of sampling Marathon #3 that it is possible to have giardia present without the presence of coliform bacteria.

- Single sampling events are insufficient to determine the direct influence of surface water on groundwater.

TABLE I

SAMPLE RESULTS FROM PHASE I

Location	Well Number	Well Depth(ft)	Well Type	Turbidity (NT"	Conductivity (Ps/cml	Temperature (°C)	Bacteriology	Macro-organisms
Neillsville	3	30.5	Sand & Gravel	< 0.5*	*	*	5 of 5	Iron Oxides Iron Bacteria
Neillsville	4	47	Sand & Gravel	5*	*	*	Safe	Iron Oxides
Cadott	3	50	Sand & Gravel	< 0.5*	8	8	98/100 ml	None
Marshfield	16	56.5	Sand & Gravel	.09 to .55	.247 to .290	8.6 to 9.1	1/100 ml	Iron Bacteria & Free Living Bact.
Marathon	3	75	Sand & Gravel	.055 to .09	.217 to .231	8.8 to 9.5	0/100 ml	Giardia, Iron Bacteria Free Living Bact
Neillsville	3	30.5	Sand & Gravel	.07 to .22	.151 to .160	7.2 to 8.0	0/100 ml	Iron Bacteria, Iron Oxides Free Living Bact
Greenwood	1	34	Dug (Granite)	.23 to 82	.191 to .202	8.6 to 9.3	overgrown 22/1 00 ml	Iron Oxides, Fungai, Spores, Plant Cells, Diatoms
Sherwood	1	87	Limestone	.06 to .17	.06 to .17	9.6 to 10.0	overgrown 8/100 ml	Iron Oxides, Iron Bacteria, Free Living Bact
Marathon	3	75	Sand & Gravel	.05 to .11	.222 to .238	9.0 to 9.9	0/100 ml	Iron Oxides, Iron Bacterial Free Living Bact
Sturgeon Bay	10	477	Limestone	.13 to .40	.494 to .559	8. 8 to 9.2	overgrown 5/100 ml	Iron Oxides, Iron Bacteria, Free Living Bact
Rhinelander	4	80	Sand & Gravel	.06 to .1 6	.210 to .241	7.8 to 8.7	8/100 ml	Iron Oxides, Iron Bacteria, Free Living Bact
Kellnersville	1	450	Limestone	.05 to .81	.567 to .628	9.1 to 9.6	2/100 ml	Iron oxides, Iron Bacteria, Free Living Bact
Loyal	1	30	Dug (Sandstone)	.05 to .1 4	.537 to .560	9.5 to 11.6	overgrown 1/100 ml	Iron Oxides, Fungus, Bacterial
			Dug				overgrown	Iron Oxides,

Location	Well Number	Well Depth(ft)	Well Type	Turbidity (NT"	Conductivity (Ps/cml	Temperature (°C)	Bacteriology	Macro-organisms
Thorp	8	40	(Sandstone)	.11 to .40	.255 to .261	7.5 to 8.0	13/100 ml	Iron Bacteria
Durand	4	138	Sand & Gravel	.10 to .30	.488 to .509	9.4 to I 0.0	16/1000 ml	Iron Oxides, Iron Bacteria
Kewaunee	2	612	Dolomite	.03 to .10	.673 to .780	8.2 to 8.6	17/1 00 ml	None, Iron Oxides
Maiden Rock	1	361	Sandstone	.18 to 40	.531 to .537	9.7 to 10.1	overgrown 58/100 ml	Iron Bacteria, Heavy Particulate
Pepin	2	121	Sand & Gravel	.04 to .10	.509 to .536	11.0 to 11.7	0/100 ml	None, Iron Oxides
Dickeyville	2	902	Limestone/ Sandstone	.05 to .50	.589 to .606	12.1 to 12.6	0/100 ml	No Test
Madison	19	808	Sandstone	.05 to .15	.522 to .549	10.8 to 11.1	0/100 ml	Iron Bacteria

PHASE II

Phase II of the study consisted of 6 individual sampling events at 3 of the Phase I sampling locations. As in Phase 1, the filter sample for giardia and macroorganisms was collected during an 8 hour sampling period with approximately 1,000 gallons of water passing through the filter. Coliform bacteria samples were collected at the beginning and the end of each sample period. The three sampling locations were selected to represent a "worst case" representation of the original 18 sampling locations. Cadott well #3 had the highest coliform bacteria count (98/100 ml). Marathon well #3 had an unconfirmed giardia detect in phase I. Rhinelander well #4 has been documented to be subject to color changes during high-water conditions. All three locations have had recurring raw water total coliform positives and are proximate to surface water.

PHASE II RESULTS

The results of phase II are presented in Table 2. As can be seen in the table none of the sampling locations test positive for coliform bacteria, giardia or macroorganisms during any of the sampling events.

PHASE II DISCUSSION AND CONCLUSIONS

Because no giardia were detected in any of the samples, the Phase II sampling provides little information for development of a method for predicting which groundwaters are under the direct influence of surface water. This is especially true given the detect of giardia at Marathon well #3 during Phase I of this investigation. However, the data do support the conclusions of Phase I of this study. Therefore, based on the results of the Phase II sampling, it is concluded that:

- Giardia is not routinely present in the most susceptible municipal groundwater supplies in Wisconsin.

TABLE 2
RESULTS OF PHASE II SAMPLING

Location	Well Number	Sampling Date	Coliform Bacteria	Giardia & Macroorganisms
Cadott	3	9/19/91	0/100 ml	None
	3	10/21/91	0/100 ml	None
	3	11/18/91	0/100 ml	None
	3	3/16/92	0/100 ml	None
	3	4/20/92	0/100 ml	None
	3	5/18/92	0/100 ml	None
Marathon	3	9/12/91	0/100 ml	None
	3	10/15/91	0/100 ml	None
	3	11/12/91	0/100 ml	None
	3	3/9/92	0/100 ml	None
	3	4/13/92	0/100 ml	None
	3	5/11/92	0/100 ml	None
Rhinelander	4	9/5/91	0/100 ml	None
Rhinelander	4	10/7/91	0/100 ml	None
	4	11/4/91	0/100 ml	None

Location	Well Number	Sampling Date	Coliform Bacteria	Giardia & Macroorganisms
	4	12/2/91	0/100 ml	None
	4	1/6/92	0/100 ml	None
	4	2/3/92	0/100 ml	None

PHASE III

Phase III of the study consisted of collecting well construction, aquifer characteristics, and locational information for the 18 sampling locations and calculating impacts of pumping on the surface water and time of travel from the surface water to the well for the three sites sampled in Phase II of the study.

PHASE III RESULTS

As can be seen in Table 3, Phase I was conducted at a wide cross section of locations to evaluate susceptibility under a variety of conditions. All three of the Phase II locations were near a surface water source. As can be seen in Table 4, provided the surface water and groundwater are hydrogeologically connected, the results of the theoretical calculations indicate that an influence of surface water on the groundwater would occur during normal operation of the three wells. This assumption is supported at Rhinelander well #4 by the reported color changes during periods of high surface water levels and at all three locations by recurring total coliform positives (unsafes).

PHASE III DISCUSSION AND CONCLUSIONS

The calculated time of travel from the surface water to the well in Phase II was 12.5 days at Marathon, 3.8 days at Cadott, and 2.8 days at Rhinelander. With the potential for giardia cysts to survive 2 months at 8^{o}C (Bingham, A. K., et al 1979, Giardia, Exp. Parasitol. 47:284) it is evident that the separation from surface water does not provide adequate time for giardia inactivation unless the cysts are filtered by the aquifer material. The calculations also support the hydrogeologic interconnection between surface and groundwater as evidenced by the theoretical drawdown occurring at the surface water during the normal operation of the wells.

Based on the evaluation of construction and location data it can be concluded that:

- The separation distance between the surface water sources and the wells sampled in Phase H would not allow sufficient time for inactivation of giardia cysts.

- The wells sampled in Phase II will be influenced by the surface water provided they are hydrogeologically interconnected.

TABLE 3
WELL CONSTRUCTION AND LOCATION INFORMATION

Location	**Well Number**	**Well Depth (ft)**	**Well Type**	**Casing Length (ft)**	**Screen Length (ft)**	**Pumping Rate (GPM)**	**Specific Capacity (GPM/ft)**	**Distance to Surface Water (ft)**
Cadott	3	50	Sand & Gravel	38	12	225	19	Stream at 60
Dickeyville	2	902	Limestone/ Sandstone	350	552 (open hole)	315	12	None Nearby
Durand	4	135	Sand & Gravel	114	24	800	164	None Nearby
Greenwood	1	34	Dug (Granite)	Unknown	None	160	Unknown	Spring at 250
Kellnersville	1	450	Limestone	120	330 (open hole)	225	2	None Nearby
Kewaunee	2	612	Dolomite	59	553	600	64	Lake at 300
Loyal	1	95	Dug (Sandstone)	Dug Well to 30	Drillhole to 95	90	Unknown	Stream at 180
Madison	19	718	Sandstone	260	458 (open hole)	2200	14	None Nearby
Maiden Rock	1	361	Sandstone	73	285 (open hole)	300	Unknown	River at 400
Marathon	3	75	Sand & Gravel	37	38	289	18	Improperly Aban- -doned Well at 70
Marshfield	16	56.5	Sand & Gravel	41	15.5	500	Unknown	Stream at 30
Neilliville	3	30.5	Sand & Gravel	25.5	5	175	16.1	River Meander at 50
Neillsville	4	46.5	Sand & Gravel	32.5	14	400	32.9	Pond at 250
Pepin	2	121	Sand & Gravel	110	11	360	Unknown	None Nearby
Rhinelander	4	80	Sand & Gravel	50	30	1500	133	Swamp at 100
Sherwood	1	87	Limestone	59	28 (open hole)	106	12.9	None Nearby
Sturgeon Buy	10	477	Dolomite	170	307 (open hole)	700	7.1	None Nearby
Thorp	8	40	Dug (Sandstone)	20	20	75	Unknown	None Nearby

TABLE 4

Summary of Aquifer Calculations for Phase II Wells

Community	Cadott	Marathon City	Rhinelander
Well Number	3	3	4
Distance to nearest surface water (ft)	60	75	100
Distance of travel during sampling period (ft)	35	22.7	59
Distance of travel during normal operation (ft)	30.7	19.8	59.5
Time of travel from nearest surface water during normal pumping (ft)	3.8	12.5	2.8
Resultant draw-down at surface water during sampling period (ft)	1.36	1.33	2.0
Resultant draw-down at surface water during normal operation (ft)	1.14	1.02	2.0

SUMMARY OF INVESTIGATION

The results of the investigation did not confirm the presence of giardia cysts in water from any of the wells sampled. Giardia were present in a single sample from well #3 at Marathon. The lack of giardia cysts could potentially be attributed to one or more of the following:

- Inadequate sampling and handling procedures (causing a failure to capture and preserve the giardia cysts).
- Inadequate analytical techniques (causing a failure to identify the giardia cysts).
- Absence of or insufficient concentrations of giardia cysts in the surface water source (preventing detection of giardia under any circumstances).
- Adequate separation between wells and surface water to allow for inactivation of giardia cysts (causing the cysts to be eliminated before reaching the well).
- Adequate well construction methods and aquifer materials to retain giardia cysts within the aquifer and allow inactivation to occur (causing the cysts to be eliminated before reaching the well).
- Absence of a direct hydrogeological connection between the surface water source and the well (preventing giardia cysts from entering the groundwater).

Because of the difficulty in sampling and analyzing for giardia cysts and the complexity of the interrelationship between groundwater and surface water it is unlikely that any study design could guarantee that a single sampling event would accurately evaluate the potential for giardia cyst presence in a groundwater supply. Increasing the information on the inter-relationship between groundwater and surface water and increasing the number of samples collected would increase the accuracy of determining the presence of giardia in groundwater. However, based on the data collected during this study, the potential for changing hydrogeological conditions (due to variations in pumping, groundwater levels, surface water levels, and recharge), and the lack of precision inherent in the sampling and analytical techniques for giardia it is unlikely that sufficient sampling and investigation could be conducted to accurately predict the susceptibility of every well to giardia cyst contamination under all conditions. The following, however, were used to reduce the influence of unknowns during this study:

- The sampling and analytical methods used during this study were selected based on an evaluation of sampling and analytical techniques to maximize the detectibility of giardia cysts.
- The calculations done during Phase III of the study show that the time of travel from the surface water to the well would not allow for inactivation of giardia cysts.
- The calculations done during Phase III and the historical recurring total coliform positive raw water samples support the assertion of a hydrogeological connection between the surface water and the groundwater supplied to the wells.

Two potential rationales remain for the lack of giardia detection during the study. They are:

- Absence of or insufficient concentrations of giardia in the surface water.

- Adequate well construction methods and aquifer materials to retain giardia cysts within the aquifer.

CONCLUSIONS

Based on an evaluation of the information from Phases I, II and III, the following conclusions are drawn: -

- Giardia cysts are not routinely present in the most susceptible municipal groundwater supplies in Wisconsin.

- Multiple sampling events cannot conclusively determine the potential for giardia contamination of groundwater supplies.

EVALUATION OF STUDY GOALS

As stated earlier in this report there were three goals to this study. They were:

1. To evaluate the extent of groundwater systems in Wisconsin that may be classified as groundwater under the direct influence of surface water as defined in Federal Register, Vol. 54, No. 124, and NR 109.04(20) WAC.

2. To evaluate the use of chronic bacteriologically 'unsafe' (total coliform positive) water problems as a screening mechanism for groundwater systems to be classified under the direct influence of surface water.

3. To evaluate the use of other indicator parameters as potential surrogates to be used when determining groundwater as under the direct influence of surface water.

The sites chosen for sampling during this study were selected to represent the 'worst case" sampling history. The sites selected represent those wells most likely to be under the direct influence of surface water. The results of the study offer no conclusive evidence of continuing influence of surface water at any of the sampling sites. Therefore, the potential for detection of giardia in any municipal well in Wisconsin is small. Additionally, because the other-than-municipal and non-community wells are constructed under existing well construction codes and utilize the same aquifer systems as the municipal wells the likelihood of detection of giardia in any OTM or non-community well is small. As the sites represented the worst case locations it can be conjectured that there are no municipal groundwater systems in Wisconsin that may be currently classified under the direct influence of surface water.

Results of raw water total coliform sampling during Phase I of the study indicate that 13 of the wells were producing bacteriologically unsafe water and 7 of the wells were producing bacteriologically safe water. The giardia positive at Marathon occurred when the well was producing bacteriologically safe water. Based on the sampling results there is no direct correlation between total coliform positive results and giardia positive results. However, based on the number of total coliform positive results, it appears that, while raw water total coliform would not be an ideal surrogate, it would, because of the more frequent occurrence of total coliform positives, be a conservative screening mechanism especially if coupled with proximity to surface water determinations to compensate for the lack of correlation between raw water total coliform positives and giardia positives.

Turbidity, conductivity, and temperature were evaluated as potential surrogates for use when determining the influence of surface water on groundwater. During Phase 1, all three parameters varied at each of the sampling sites. However, there does not appear to be a correlation between the variations and the occurrence of giardia. Additionally, it is difficult to assess the gradual changes exhibited by the parameters during the Phase I sampling. Therefore the use of turbidity, conductivity, or temperature as a surrogate for giardia would appear to be of little value. More appropriately these parameters should be used in conjunction with a comprehensive evaluation using a number of investigative tools.

PROPOSED METHODOLOGY

In Phase I of the study, it was concluded that the coliform bacteria test is not an ideal surrogate for the giardia test. Additionally, based on the results of this study and examination of other research efforts on the occurrence and detection of giardia, it appears that there is no single approach (such as use of a surrogate) or combination of approaches (such as use of a surrogate in conjunction with a hydrogeological investigation) that would provide an accurate predictive tool for susceptibility to giardia contamination. Selection of an approach is hampered by the poor recovery rates for giardia sampling and analysis and the variability in environmental conditions (water levels, recharge rates, rainfall events, occurrence of giardia cysts, etc.). Increasing the number of approaches used and increasing the frequency of sampling should increase the accuracy and reliability of the predictive tool. The 'best' predictive tool would likely consist of collecting environmental data (rainfall events, water levels, occurrence of giardia, etc.), collecting hydrogeological data (aquifer characteristics, well construction data, pumping test results, etc.) collecting water quality data (temperature, pH, turbidity, coliform, etc.) and collecting giardia sampling data. The large effort involved with using this type of approach would be manageable for investigation of a single well or well field. It would not be manageable for a large scale evaluation, such as a review of the 15,000 public wells in Wisconsin.

Since the workload associated with implementing the "best" predictive tool would be unmanageable on a statewide basis and since no "ideal' surrogate exists for giardia testing, with the possible exception of cryptosporidium (see note), it is necessary that an alternate management approach be implemented to evaluate groundwater under the direct influence of surface water. To provide a manageable yet protective approach, the WDNR will assess each groundwater supply for the "direct influence of surface water: by evaluating:

1. Raw water total coliform positives,
2. Well construction, and
3. Well location.

Historic bacteriological sampling records will be reviewed to determine total coliform results. Well construction and location will be reviewed where it appears that they do not meet the appropriate requirements of the well construction codes, NR 811 and NR 112. Because the well construction and locational requirements of NR 811 and NR 112 have been in effect in some form since the 1930's and the public water supplies are routinely inspected for construction and locational deficiencies, all wells will initially be considered to meet construction and location requirements.

Coliform bacteria was chosen because it has long been associated with the influence of surface water. Additionally, it is felt that its higher concentration in surface water, its higher occurrence frequency in surface water, and its higher analytical reliability and repeatability balance the longer viability of giardia making it a reasonable surrogate for routine giardia monitoring in untreated groundwater. The evaluation of groundwater under the influence of surface water will be incorporated into the current policy of the WDNR requiring upgrading or replacement of wells that do not meet the standards of NR 811 and NR 112 and requiring replacement of wells that, on a recurring basis, test bacteriologically unsafe (total coliform positive). The proposed state policy is illustrated in Figure 1. The replacement of wells that have recurring total coliform positives will be, in most cases, a more conservative approach than replacement or treatment of wells that would be susceptible to giardia contamination. This is supported by the Phase II sampling of three bacteriologically unsafe wells at Cadott, Rhinelander, and Marathon. The well at Cadott has been ordered to be replaced, the well at Rhinelander is receiving treatment (consisting of chlorination and detention) and the well at Marathon has been documented to produce bacteriologically safe water. None of these wells have been shown to be susceptible to giardia contamination.

Note: Concentrations of Cryptosporidium cysts and Giardia cysts were significantly correlated in a Survey of Potable Water Supplies for Cryptosporidium and Giardia, Rose, et al., Environ. Sci. Technol., Vol. 25, No. 8, 1991. Because of this Cryptosporidium may be a useful surrogate for Giardia. However, the difficulties in sampling for Giardia also exist for Cryptosporidium.

<u>FIGURE I</u>

STATE POLICY FOR GROUNDWATER UNDER THE
DIRECT INFLUENCE OF SURFACE WATER.

Well is
Not under
the Direct
Influence of
Surface Water
|
No|
|

START

Well meets
NR 811
or N-R 112
construction
and location
standards

Yes→ Recurring Raw Water Total Coliform Positives Yes → Fecal Coliform or Enterococci Positive Yes → Confirmed Giardia Positive Yes → Well is Under the Direct Influence of Surface Water

Fecal Coliform or Enterococci Positive
|
No
|
v

Confirmed Giardia Positive
|
No
|
v

|
No
|
Reoccurring
Raw Water
Total Coliform
Positives -- No →
|
Yes
|
Fecal
Coliform
or
Enterococci
Positive -- No →
|
Yes
|
Confirmed
Giardia
Positive -- No →
|
Yes
|
Well is
Under
the Direct
Influence
of surface
Water

The well is not under the direct influence of surface waters. However, state requires reconstruction or replacement of the well. If an alternate source of bacteriologically safe water is not available the state may allow treatment.

A 3 log removal of Giardia must be provided by treatment approved in lieu of replacement of the well.

* Recurring raw water total coliform positives - two or more raw water coliform positives in any two year period that are not attributed to work on the well.